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ABSTRACT

This paper considers five possible analyses to explain dental alternations in Japanese and argues that the formulation approximating the actual historical development is likely to provide the most satisfactory synchronic description. The approaches considered are distributional analysis, strict historical interpretation, modified historical interpretation, restructured analysis, and crazy interpretation. The paper concludes that the modified historical interpretation and restructured analysis have the greatest potential since they both restructure versions of the historic changes. (VM)

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Crazy Rules and Natural Rules in Japanese Phonology

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1. Introduction. In an interesting and provocative paper, "How Do Languages Get Crazy Rules?" (1969), Bach and Harms take the position that seemingly unnatural rules in the phonology of a language result from the simplification and amalgamation of separate rules. Their application of this hypothesis to the analysis of Japanese dentals raises questions which deserve further exploration.

Because of the success modern linguistics has had in uncovering the formal structure of language and analyzing this structure in terms of formal rules, there has been a tendency in recent years to look upon language as nothing more than a body of rules. This of course can lead to extremes. Linguists must always ask whether their rules reflect what is going on in the language or whether the rules impose an unreal structure on the language simply because the rule format makes a given rule possible and an evaluation metric attaches greater value to one formalism over another.

Phonological rules do not come ready made with a language. The most efficient language would have no phonological rules at all. Underlying and surface forms would be one and the same. No mapping rules would be required. If this is the case, why does any language tolerate phonological rules at all? The answer is straightforward enough, and fairly simple. Phonological rules arise quite inadvertently as the result of historic sound changes which disrupt the direct relationship of underlying and surface forms. Sound change seems to be an inescapable part of language. Its causes, which are not fully understood, are beyond the scope of this paper. It is sufficient for our purposes merely to point out that the process of sound change typically affects an entire class of sounds in a particular environment, leaving a post-change residue of semantically and paradigmatically related morphs which no longer share the same phonetic makeup. At this point speakers of the language must either expand their lexicon to encompass two (or more) entries for each affected morph or add to their grammar a general rule which will act on the original dictionary entries to produce the appropriate post-change forms. Considerations of economy and, to a lesser extent, psychological validity have led linguists to the currently prevailing view that speakers adopt a general rule which is, essentially, a statement of the sound change which actually took place.

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One might suppose that analyzing the phonology of a language is simply a matter of reconstructing the sound changes that have taken place and formulating a set of ordered rules which state these changes. Unfortunately, it is not this simple for several reasons. (1) The phonological rules now operating in the languages of the world have all been built upon earlier phonological systems which were themselves the residue of still earlier irregularities held together by similar phonological rules. (2) As layers of rules are added to previous rules, there is an interplay between rules and the base forms on which they operate with the result that rules are occasionally obscured beyond recovery (i.e. they disappear) and base forms are periodically restructured. (3) There is no evidence that restructuring of rules and/or base forms proceeds uniformly for every speaker of a language, nor is it necessary to assume that all speakers of the same contemporary language rely on the same base forms and phonological rules to produce mutually intelligible utterances. (4) Given these variables, there is no simple algorithm for determining what a reasonable base form might be or what a reasonable set of phonological rules acting on it might look like.

This does not mean that linguists are altogether adrift in the realm of phonology. As a rule of thumb, Chafe's proposal (1970:38) "to describe the language as it would be if a speaker were to take maximum advantage of all the generalizations which could be made" seems reasonable. But we are still left to determine what kind of rules are in some sense 'natural' and therefore acceptable in a phonology, and what kind are 'unnatural' and unacceptable. The origin of phonological rules in the process of historic sound change is the one fixed point that offers the best hope for defining a 'natural' synchronic rule. A natural rule (or rule sequence) is none other than a possible sound change (or series of changes). A possible rule amalgamation can hardly be a combination of any two rules that apply to the same class of sounds--although devices such as alpha notation and angled brackets provide a way to collapse rules synchronically even when the rules must have had separate historical origins. It seems more likely that rule amalgamation occurs when two conflicting rules, for example those originating in different dialects, are eventually resolved in some arbitrary way by an emerging 'standard' dialect. The notion of rule 'simplification' is therefore dependent upon an understanding of the possibilities for rule restructuring that exist at any point in history. The notion must ultimately be tied to some empirically verifiable concept of psychological validity. In particular, it cannot be assumed that a single rule which subsumes a sequence of two (or more) ordered rules is <u>a priori</u> simpler than the corresponding--presumably historical--rule sequence. A 'crazy' rule then may simply be one resulting from linguistic overexuberance. If so, it should be a demonstrably impossible rule, either by encompassing an impossible historical change or by amalgamating disparate portions of two (or more) rules in a way that fails to correspond to alternative formulations which have stronger claims to historical or psychological validity.

2.0. Japanese Dentals. Applied to the analysis of Japanese dentals, the foregoing principles can do little more than help us choose the least objectionable of several possible alternatives, all of which are unsatisfactory in some respects. If we rely on history for guidance, we quickly discover that the present alternations in the dental series are built on an earlier system of similar, but slightly different, alternations. This in turn is built on an earlier system that involved still other alternations, and so on as far back as the language can be reconstructed. Clearly we are dealing with a situation where restructuring has taken place, and presumably we must fall back on some notion of psychological reality to identify the proper base forms and appropriate phonological rules.

2.1. Distributional Analysis. One possibility that cannot be ruled out automatically is an analysis corresponding roughly to the Hepburn romanization or to Bloch's phonemic analysis (1950). The two, while differing in details, are merely variant forms of the same basic distributional analysis. This is evidently the approach that Miller (1967) prefers, judging from his assertion that the Hepburn romanization is probably "closest to the phonemic solution that most linguists would prefer today." (229) A head count of linguists presumably would either confirm Miller's assertion by showing Bach and Harms, among others, to be in the minority; or it might show the statement to be a projection of Miller's own minority views.

The distributional analysis does not greatly expand the inventory of basic phonological segments, and it has the distinct merit of reducing the number of phonological rules. It results in the defective distribution of certain segments (for example, /s/ does not occur before /i/ although it precedes all other vowels), but the significance of this is open to question since we may well ask whether the average speaker worries a great deal about forms that do not exist in his language or simply concentrates on producing the forms that he knows do exist. In a distributional analysis, the alternation of s and š in verb paradigms is treated as a minor inflectional rule which substitutes š for s as part of an inflected ending in which the next segment, by coincidence, is i. The rule need be stated only once for a whole class of verbs. In fact, if the rule is stated in terms of the kana syllabary which itself defines the defective distribution of s, the problem is automatically resolved. (The question of whether Japanese verbal inflections can effectively be analyzed in terms of the kana syllabary is of course a separate problem.)

Martin's treatment of Japanese morphophonemics (1952:21), based on a phonemic analysis, covers not only the s/š alternation but related alternations in a single paragraph:

> The phoneme t does not occur before u; when verb bases ending in t are joined to verb endings beginning with u, the base-final phoneme t is automatically replaced by c. The phonemes s, t, and c do not occur before i or y. When verb bases ending in s or t are joined to verb endings beginning...with i, the final stem phonemes s and t are automatically replaced by š and c respectively.

One may well ask, however, whether Martin's formulation is not in fact merely a process statement couched in phonemic terminology.

Mention of the kana syllabary raises another interesting question--whether for a literate speaker of Japanese psychological reality of phonological patterns is defined in terms of alphabetic segments or syllable types. This could be tested by devising a controlled study matching literate speakers against a group consisting either of pre-school children, illiterates, or speakers literate only in an alphabetic system of writing. If, in the course of such a study, we ask the participants to produce sequences of s followed by various vowels, we are likely to find that everyone regardless of background systematically substitutes š for s before i. Such a substitution pattern is common for Japanese speakers attempting to master a foreign language. The regularity and predictability of this pattern is actually a strong argument against the distributional analysis because it constitutes evidence that the non-occurrence of s before i is not accidental but is systematically prevented by a process (i.e. rule) which substitutes š in this environment. A purely distributional statement does not account for this pattern, and any supplementary statement of the relationship effectively converts the original distributional (i.e. phonemic) statement into a generative (i.e. morphophonemic) statement.

2.2. Strict Historical Interpretation. The historical development of Japanese dentals, as already noted, is complicated enough that no single best solution automatically emerges. For convenience let us designate the dental series by their Japanese names: ta-gyo, da-gyo, sa-gyo, za-gyo. In the Nara Period both ta-gyo and da-gyo appear to have had the consonants t and d respectively before all vowels. However, sa-gyo and za-gyo were probably affricated to ts and dz before a, u and o--although an alternative analysis assigns them the phonetic values š and ž before all vowels (cf. Miller 1967: 191-192). In the Heian Period ta-gyo and da-gyo remained unchanged; sa-gyo and za-gyo were deaffricated before a, u and o but became palatalized (i.e. š and ž) before i and e. The alternative analysis would hold that these two series were depalatalized before a, u and o (cf. Miller 202).

Regardless of how the language arrived at this stage, it seems quite clear that this is the stage which (historically at least) underlies the alternations of modern Japanese. Subsequent historic changes are as follows:

(1) Affrication (Miller 224)

$$\begin{bmatrix} t \\ d \end{bmatrix} \rightarrow \begin{bmatrix} ts \\ dz \end{bmatrix} \; /__u$$

Affrication and Palatalization (Miller 224)

$$\begin{bmatrix} t \\ d \end{bmatrix} \rightarrow \begin{bmatrix} t\underline{\underline{s}} \\ d\underline{\underline{z}} \end{bmatrix} \; /__i$$

Neutralization (Miller 224)

$$\begin{bmatrix} \underline{\underline{s}} \\ \underline{\underline{z}} \\ dz \end{bmatrix} \rightarrow \begin{bmatrix} d\underline{\underline{z}} \\ z \end{bmatrix} \; /___\begin{bmatrix} i \\ u \end{bmatrix}$$

Depalatalization (Miller 228)

$$\begin{bmatrix} \underline{\underline{s}} \\ \underline{\underline{z}} \end{bmatrix} \rightarrow \begin{bmatrix} s \\ z \end{bmatrix} \; /___e$$

Even if we assume that these rules represent the actual historical development, one important consideration suggests a restructuring of the rules for purposes of a synchronic description. The depalatalization of $\underline{\underline{s}}$ before e (assuming it actually occurred) left no residue to point toward $\underline{\underline{s}}$ as the underlying form for s and $\underline{\underline{s}}$ in modern Japanese. On the contrary, the regular substitution of $\underline{\underline{s}}$ for s before i points toward s as the base form.

2.3. Modified Historical Interpretation. We might therefore propose the following alternative rules as a modified historical interpretation:

(2) Affrication

$$\begin{bmatrix} t \\ d \end{bmatrix} \rightarrow \begin{bmatrix} ts \\ dz \end{bmatrix} \; /___\left\{\begin{matrix} i \\ u \end{matrix}\right\}$$

Palatalization

$$\begin{bmatrix} s \\ z \end{bmatrix} \rightarrow \begin{bmatrix} \underline{\underline{s}} \\ \underline{\underline{z}} \end{bmatrix} \; /___i$$

Neutralization

$$\begin{bmatrix} \text{ʃ} \\ \text{dz} \end{bmatrix} \rightarrow \begin{bmatrix} \text{dʃ} \\ \text{z} \end{bmatrix} / __ \begin{bmatrix} \text{i} \\ \text{u} \end{bmatrix}$$

The handling of affrication and palatalization seems more natural in (2) and in some ways may be a more correct statement of the actual historical developments. This is especially so if we can assume that ʃ and ʒ were depalatalized before e (perhaps before i as well) at the beginning of the period under discussion. This would allow the palatalization rule of (2) as a genuine innovation or, at the very least, make it an artifact of a system in which the only surviving palatalized sibilant happened to occur before i. Note that if we assume affrication of t and d before i and u as the first change, the subsequent palatalization of s and z before i very neatly accounts for the major alternations of all four series in a single step. This remains equally true even if we assume that palatalization historically preceded affrication--so long as we assume that palatalization was a persistent rule (cf. Chafe 1968) and was able to act on the output of the affrication rule. The neutralization rule, which is the same in both (1) and (2), appears unnatural in that the leveling proceeds in different directions in the two instances covered by the modern rule. Although alpha conventions allow for the collapse of such processes, it seems reasonable to suppose that the two parts of the rule originated as separate processes, most likely in different dialect areas which neutralized the distinctions in opposite directions. The fairly common phenomenon of dialect borrowing (Miller 128) eventually brought the two patterns together so that part of each pattern was adopted in the Tokyo dialect, thus creating the possibility of merging the productive portions of two historically conflicting rules. If this account is correct, the neutralization rule proposed here is not an actual historic process in its own right but rather a compromise between two conflicting processes (cf. Wang 1969).

McCawley's treatment of Japanese phonology (1968) should also be classified as a modified historical interpretation. His rule formulation is based on the Jakobson-Fant-Halle feature system (1951) in use prior to Chomsky-Halle (1968), making comparison with the Bach and Harms formulation somewhat difficult. Moreover, McCawley is primarily concerned with other aspects of Japanese phonology and gives scant attention to the processes under discussion here. It is significant, however, that for McCawley affrication and neutralization are late rules, numbered 27 and 28 respectively (1968:127-128) in a linear sequence of 33 rules preceded by two additional rules designated A and B. Since McCawley regards palatalization as a sequence of consonant plus /y/ (cf. 75-77), he has no palatalization rule as such.

2.4. Restructured Analysis. The problem of neutralization is avoided entirely in another analysis presented as an informal proposal by Bedell (1969). The rule sequence in this approach, however, represents a greater departure from the actual historical development than in the modified historical analysis above. In this approach, d is first changed to the fricative z. Subsequent affrication and palatalization rules then apply to the output of this rule and to the other dentals to produce the alternations of modern Japanese without a specific neutralization rule. The rules are as follows:

(3) Spirantization (≡ Neutralization)

$$d \rightarrow z \quad / __ \left\{ \begin{matrix} i \\ u \end{matrix} \right\}$$

Affrication

$$t \rightarrow ts \quad / __ u$$

Palatalization and Affrication

$$\begin{bmatrix} t \\ s \\ z \end{bmatrix} \rightarrow \begin{bmatrix} t^{\breve{s}} \\ \breve{s} \\ d\breve{z} \end{bmatrix} \quad / __ i$$

This approach seems to tie in nicely with other phonological processes which are beyond the scope of this paper. Moreover, the rules form a tidy statement as presented above--and an even neater statement if single units c, $\breve{c}$, $\breve{j}$ are used instead of ts, $t\breve{s}$, $d\breve{z}$. However, the rules are somewhat more complex when stated in terms of features. Each of the first two rules applies to an individual segment rather than a class of segments, and the last rule combines two different processes. All three rules must therefore contain fairly detailed feature specifications, and the last rule must further employ a combination of braces and angled brackets.

2.5. Crazy Interpretation. Bach and Harms propose a single rule which they acknowledge as having a crazy appearance but defend as a reasonable simplification and amalgamation of the presumed sequence of sound changes that gave rise to it. Their reconstruction of these sound changes, however, is considerably different from that discussed above and seems to be more influenced by the notational possibilities for rule construction than by historic evidence. Their first rule (J1, p. 18), which they call a "quite plausible rule palatalizing the dentals before /i/," also includes the affrication of t and d in this environment. They present the rule (to which I have added SD, SC and ENV to facilitate discussion) in terms of the following features:

(J1) SD [-sonorant, +coronal] → SC [+del rel, +strident, -anterior] / ___ ENV [V, +high, -back]

Bach and Harms give no feature analysis of the segments which are available for this rule to act on at the time it applies (see Appendix for a possible feature analysis); but we must assume that flapped r, phonetically similar to d, is not affected by the rule. This could be achieved most easily if we assign r the feature [+sonorant], allowing it to agree with d in all other features. (Another possibility would be to treat r as [+continuant], an analysis favored by Chomsky and Halle (1968:318). This would require specification of the feature [-continuant] in the SD of (J1) and would prevent the rule from applying to s and z, which are both [+continuant]. If r is assumed to be both [+sonorant] and [+continuant], the rule as written will apply to the correct segments.) Note, however, that the rule as formulated by Bach and Harms will assign [+delayed release] to s and z. This surely is not intended. It can be avoided by adding in angled brackets the feature [-continuant] in the SD and pairing it with [+delayed release] in the SC. This results in a somewhat more complicated rule, and the presence of angled brackets suggests that the rule may actually be an amalgamation of two separate processes. Given an appropriate universal convention, angled brackets could of course be avoided. The convention would have to specify that certain features (e.g. [+delayed release]) are to be disregarded whenever added to segments to which they are inherently inapplicable (e.g. s and z) if these segments happen to be included in a natural class containing segments to which the feature actually is applicable. No such convention has, to my knowledge, been proposed. Nor is it easy to see how it could ever be justified. Indeed, the adoption of such a convention would open the doors to all kinds of arbitrary contrivances. We must therefore assume that angled brackets are required in this case.

Bach and Harms suggest as a second step that "the rule was generalized in some dialects by alpha-generalization over anterior and back" (18). This they give as Rule J2:

(J2) SD [-sonorant, +coronal] → SC [+del rel, +strident, αanterior] / ___ ENV [V, +high, αback]

It is undoubtedly true that sound change may come about as speakers extend the original environment of a rule or as the result of articulatory assimilation which is represented in rules by the

alpha convention. But in the case of (J2) the "generalization" could equally well result from the amalgamation of two separate processes, one involving dentals before i and the other involving the same segments before u. Note that this rule must be emended in the same way as (J1) to exclude r from the SD and prevent s and z from being assigned the feature [+delayed release] in the SC. The output of (J2) is the same as (J1) except that t now becomes ts and d becomes dz before u. Anterior switch for s and z is vacuous in this case. The rule (J2) produces the alternations that presumably existed before neutralization of ʒ and dz to dʒ and z respectively.

Bach and Harms suppose that neutralization came about by the addition of the following rule (19):

(J3) $$\begin{bmatrix}\text{SD}\\ -\text{sonorant}\\ +\text{strident}\\ +\text{voice}\\ +\text{anterior}\end{bmatrix} \rightarrow \begin{bmatrix}\text{SC}\\ +\text{continuant}\end{bmatrix}$$

Actually, [-sonorant] is not required in the SD since dz and z are the only segments to which the remaining description could apply. Probably the SC should include [-delayed release] since this change is also necessary to get from dz to z. The rule will of course apply vacuously to z itself.

The authors then suppose that this rule was also generalized by an alpha convention (19):

(J4) $$\begin{bmatrix}\text{SD}\\ -\text{sonorant}\\ +\text{strident}\\ +\text{voice}\\ \alpha\text{anterior}\end{bmatrix} \quad \begin{bmatrix}\text{SC}\\ \alpha\text{continuant}\end{bmatrix}$$

The output of (J4) will be the same as (J3) except that it will also change z to dʒ and it will apply vacuously to any dʒ subject to the rule. Again it must be noted that [-sonorant] is not required in the SD. The feature [-αdelayed release] must now appear in the SC. Once again it is necessary to ask whether this rule represents a "generalization" of (J3) or is simply an artifact resulting from the amalgamation of two conflicting rules as suggested in connection with the modified historical interpretation in 2.3 above.

Having presented these four rules as a possible historical sequence, Bach and Harms offer to combine them into a single rule which does everything at once (18):

$$(J)\quad \begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ \langle +\text{voice} \rangle \end{bmatrix} \rightarrow \begin{bmatrix} +\text{del rel} \\ +\text{strident} \\ \alpha\text{anterior} \\ \langle \alpha\text{continuant} \rangle \end{bmatrix} / __ \begin{bmatrix} V \\ +\text{high} \\ \alpha\text{back} \end{bmatrix}$$

Apart from the plausibility of the overall rule, it retains specific defects, already discussed, which carry over from the component rules which it amalgamates. To remedy these defects, the following modifications are required:

$$(J')\begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ \langle +\text{voice} \rangle 1 \\ \langle -\text{continuant} \rangle_2 \end{bmatrix} \rightarrow \begin{bmatrix} \langle +\text{del rel} \rangle_2 \\ +\text{strident} \\ \alpha\text{anterior} \\ \langle \alpha\text{continuant} \rangle_1 \end{bmatrix} / __ \begin{bmatrix} V \\ +\text{high} \\ \alpha\text{back} \end{bmatrix}$$

The result is an even crazier rule than the original, but it does produce exactly the alternations which actually occur. As in the component rules, some of the structural changes apply vacuously, of course.

Bach and Harms offer a vigorous defense of (their version of) the composite rule. They anticipate (20-21) the objection that the rule is an artifact which in reality lumps together three disparate rules--palatalization, affrication and neutralization. To this, they offer three answers, which are repeated here with a brief rejoinder in each case. (1) Three separate rules would fail to capture the generalization that the three rules affect the same natural class of obstruents. However, the SD of each rule will clearly apply to the same natural class. There is no a priori reason to believe that all rules affecting the same natural class must always be collapsed. Rather, an amalgamation of rules seems to be required only under specific circumstances as, for example, with the residue of the two conflicting neutralization rules discussed above, where the discrepancy can be resolved only by rule restructuring. (2) Splitting the purported rule into three would fail to account for the fact that distribution of the rules in Japanese is not independent. However, the fact that the three rules are ordered should be enough to show the relationship. (3) No dialect of modern Japanese shows a separation of the putative rules by some other rule. However, this argument conveniently forgets that phonological rules are partially ordered, not fully ordered. The concept of partial ordering and level of application, in which all rules which do not conflict with each other occupy the same level and are ordered only with relation to rules on a higher or lower level, is developed by Chafe (1968) and need not be repeated here. A complete phonology of Japanese would presumably show affrication, palatalization and neutralization on three separate levels (i.e. ordered with relation to each other but applying simultaneously with various other rules with which

they are inherently unordered. It is natural to expect ordered rules to apply to many of the same segments (this is one of the reasons they must be ordered); but there is no reason to suppose that every set of three ordered rules, even if they apply to the same natural class, must be collapsed into a single rule.

3. Conclusion. In the preceding section we have considered five possible accounts of dental alternations in Japanese. In each case I have tried to argue that a formulation approximating the actual historical development is likely to provide the most satisfactory synchronic description. The classical phonemic treatment can hardly be considered since it makes no real statement at all about alternations. A strict historical interpretation was rejected since it would require representation of changes no longer recoverable from the alternations preserved in the contemporary language. The collapse of the historic changes into a single rule was rejected as spurious and unmotivated. This leaves two possibilities, both of them restructured versions of the historic changes. The rule sequence presented originally as (2) was called a modified historical interpretation, and the sequence presented as (3) was termed a restructured analysis. These rule sequences are repeated here in feature notation as (3') and (2'). The weaknesses of (3) which have already been noted become more apparent in feature notation. This is true, at least, if we define economy in terms of the number of features involved. It is especially true if we attach extra cost to braces and/or angled brackets. On the same basis, the economy of (2) becomes readily apparent, especially if we are willing to accept the use of alphas in the neutralization rule as a natural artifact collapsing the residue of two originally conflicting rules as suggested above.

(3') Restructured Analysis

Spirantization

$$\begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ +\text{anterior} \\ -\text{continuant} \\ +\text{voice} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{continuant} \\ +\text{strident} \end{bmatrix} \; / __ \; \begin{bmatrix} +\text{vocalic} \\ +\text{high} \end{bmatrix}$$

Affrication

$$\begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ +\text{anterior} \\ -\text{continuant} \\ -\text{voice} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{del rel} \\ +\text{strident} \end{bmatrix} \; / __ \; \begin{bmatrix} +\text{vocalic} \\ +\text{high} \\ +\text{back} \end{bmatrix}$$

Palatalization and Affrication

$$\begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ +\text{anterior} \\ \{\langle -\text{continuant}\rangle \\ \langle +\text{voice}\rangle\} \end{bmatrix} \rightarrow \begin{bmatrix} \langle +\text{del rel}\rangle \\ +\text{strident} \\ -\text{anterior} \end{bmatrix} / __ \begin{bmatrix} +\text{vocalic} \\ +\text{high} \\ -\text{back} \end{bmatrix}$$

(2') Modified Historical Interpretation

Affrication

$$\begin{bmatrix} -\text{sonorant} \\ +\text{coronal} \\ -\text{continuant} \end{bmatrix} \rightarrow \begin{bmatrix} +\text{del rel} \\ +\text{strident} \end{bmatrix} / __ \begin{bmatrix} +\text{vocalic} \\ +\text{high} \end{bmatrix}$$

Palatalization

$$[+\text{strident}] \rightarrow [-\text{anterior}] / __ \begin{bmatrix} +\text{vocalic} \\ +\text{high} \\ -\text{back} \end{bmatrix}$$

Neutralization

$$\begin{bmatrix} -\text{sonorant} \\ +\text{strident} \\ +\text{voice} \\ \alpha\text{anterior} \end{bmatrix} \rightarrow \begin{bmatrix} \alpha\text{continuant} \\ -\alpha\text{del rel} \end{bmatrix} / __ \begin{bmatrix} +\text{vocalic} \\ +\text{high} \end{bmatrix}$$

APPENDIX

Distinctive Feature Analysis of Some Japanese Consonants

	Underlying Segments										Produced by P-rules					
	k	g	s	z	t	d	n	m	r		š	ž	ts	tš	dz	dž
sonorant	-	-	-	-	-	-	+	+	+		-	-	-	-	-	-
vocalic	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
consonant	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
coronal	-	-	+	+	+	+	+	-	+		+	+	+	+	+	+
anterior	-	-	+	+	+	+	+	+	+		-	-	+	-	+	-
high*	+	+	-	-	-	-	-	-	-		+	+	-	+	-	+
voice	-	+	-	+	-	+	+	+	+		-	+	-	-	+	+
strident	-	-	+	+	-	-	-	-	-		+	+	+	+	+	+
contin	-	-	+	+	-	-	-	-	-		+	+	-	-	-	-
del rel	-	-	-	-	-	-	-	-	-		-	-	+	+	+	+
nasal	-	-	-	-	-	-	+	+	-		-	-	-	-	-	-

*The feature [+high] is predicted by the redundancy rule:
[-anterior] → [+high].

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